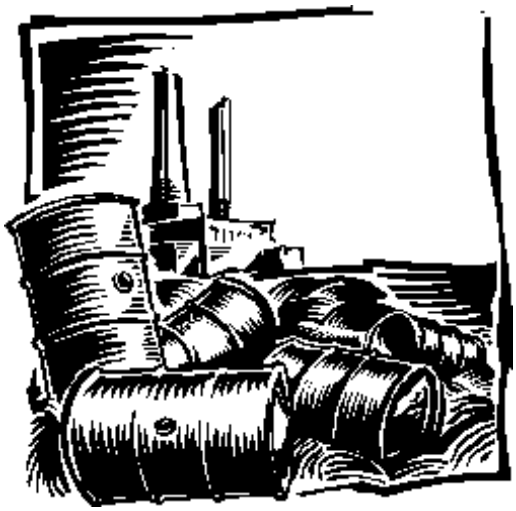
Activity 2

Examining a Hazardous Waste Site



Duration	2 class periods
Grade Level	9-12
Key Terms/ Concepts	Aquifer Contamination Hazardous waste Superfund Water table
Suggested Subjects	Chemistry Earth Science Geology Physical Science

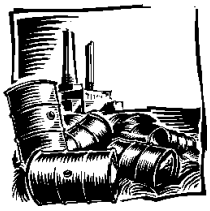
Purpose

This activity helps students understand how Superfund sites are created. They discuss what activities produce hazardous waste, and how contaminants are released and spread into the air, water, soil, and groundwater. Students learn what types of pollution can be cleaned up using Superfund authority and what types are addressed through other laws. Students construct a model to observe how contaminants move in groundwater.

Background

The U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in response to growing concern about health and environmental threats from hazardous waste sites. This law is commonly called **Superfund**. Working with states and Indian Tribal governments, Superfund requires the U.S. Environmental Protection Agency (EPA) to deal with abandoned, accidentally spilled, or illegally dumped **hazardous wastes** from the past, primarily from businesses and industry. Other types of pollution are handled by other environmental laws.

The Superfund program has a process for reporting and keeping track of potentially contaminated sites. Since the early 1980s when the law took effect, more than 37,000 hazardous waste sites have been reported. EPA must investigate each of the sites to determine the seriousness of the **contamination**. Only the most serious sites are cleaned up using Superfund authority; approximately four percent of reported sites are being cleaned up under Superfund. Sites not handled by the Superfund Program will be cleaned up by state governments or under other laws, or will require no cleanup because they pose no danger to people or the environment.



It is important to keep in mind that the Superfund Program deals only with abandoned, accidentally spilled, or illegally dumped hazardous substances. A number of other major environmental laws—such as the Resource Conservation and Recovery Act (RCRA), the Clean Water Act, the Clean Air Act, the Toxic Substances Control Act, and the Safe Drinking Water Act—were enacted to deal with other types of pollution.

To help prepare your students for this activity, use *Warm-Up 6: What is an Aquifer?* You can perform the entire Warm-Up or simply review the major points covered in it.

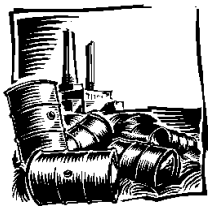
For more information on hazardous waste sites and cleanups, see the Suggested Reading list found at the end of the Haz-Ed materials. Other Haz-Ed materials that are related to the topic include *Warm-Up 2: EPA's Superfund Program—Overview.*

Preparation

1. Gather the following materials *(NOTE: You can split the class into 4 groups if desired and have each group do the experiment.)*

    - bottom part of a clear, plastic two-liter soda bottle
    - pump mechanism from a liquid soap dispenser
    - small piece of nylon fabric to cover the end of the pump tube
    - tape
    - resealable plastic sandwich bag with 2 cups of small pebbles or aquarium gravel (white or light-colored)
    - resealable bag with 2 cups of clean sand (white sand is best)
    - large coffee filter (round with a flat bottom, not cone-shaped)
    - clean spray bottle, the type spray window cleaner comes in
    - bottle of red food coloring
    - clear measuring cup (2-cup size)
    - copies for each student of:
        Fact Flash 1: Hazardous Substances and Hazardous Wastes
        Fact Flash 2: The Superfund Cleanup Program
        Fact Flash 5: Groundwater

    - copies for each student of the following maps from *Fact Flash 3: Flowing Railroad Hazardous Waste Site*
        Map 1, Flowing Railroad Site
        Map 2, Flowing Railroad Site Area
        Map 3, Diked Sludge Pond, Cross-Section



2. Read Fact Flashes 1, 2, 3 and 5 to prepare your lecture.

3. Distribute Fact Flashes 1 and 2 and assign students to read them as homework.

Procedure

Class #1

1. Review the main ideas from Fact Flashes 1 and 2.

2. Distribute Map 1, Flowing Railroad Site (from *Fact Flash 3: Flowing Railroad Hazardous Waste Site*). This is an overhead view of a fictional site showing where past industrial activities are thought to have taken place. Describe past site activities to the students, using the information in Fact Flash 3.

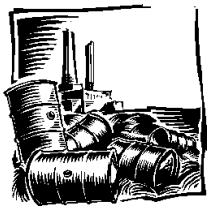
3. Distribute Map 2, Flowing Railroad Site Area (from Fact Flash 3). This is an overhead view of the towns, rivers, and some activities in the surrounding area. Describe the area to students using information from Fact Flash 3.

4. Ask students how they think contaminants might spread from the site. Possible answers include:

    - The wind can blow contaminant vapors.
    - The wind can blow small soil particles to which contaminants are attached.
    - Contaminants can be washed into the Flowing River by rainfall running off the site.
    - Liquid contaminants can flow down through the soil to the groundwater due to gravity.
    - Contaminants can be washed down through the soil to the groundwater by rainfall soaking into the soil.
    - Groundwater moving underground can spread contaminants in the aquifer.
    - Contaminated groundwater can move that uses the Flowing River.
    - Excavation or other activities that disturb the soil on the site can move contaminants.

5. Ask students how animals or plants may be exposed to contaminants from the site. Possible answers include:

    - The wind can blow contaminants to tree leaves, grasses, or crops.
    - Animals can eat contaminated plants.



- Fish and aquatic plants can be exposed to contaminants washed into the Flowing River.
- Farmland crops could be exposed to contaminants through the irrigation system that uses water from the Flowing River.

6. Ask students how people in Ruralville and Utopia may be exposed to contaminants from the site. Possible answers include:

   - Eating contaminated crops
   - Eating contaminated fish from the Flowing River
   - Utopia residents drinking contaminated water from their municipal wells
   - Ruralville residents drinking contaminated water from the Flowing River
   - Children playing on the site
   - Fishermen crossing the site to get to the Flowing River
   - Ruralville residents breathing air containing contaminated dust blown off the site
   - Ruralville and Utopia residents taking showers with contaminated water.

7. Ask students what factors would affect the amount of exposure from site contamination. Possible answers include:

   - Amount of contamination originally released at the site
   - Amount of dispersion of the contaminants
   - Amount of physical, chemical, and biological transformation of the contaminants into harmless compounds
   - Frequency of contact with contaminated water, soil, plants, and animals.

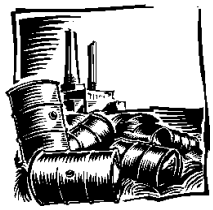
8. Explain to students that in a follow-up class, they will look more closely at how groundwater at the Flowing Railroad hazardous waste site may have been contaminated.

9. Distribute *Fact Flash 5: Groundwater* and assign students to read it prior to the next class.

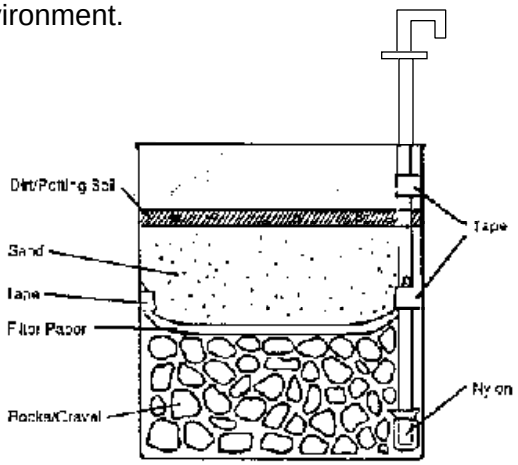
Class #2

1. Distribute Map 3, Diked Sludge Pond, Cross-Section (from Fact Flash 3). Briefly review with students the main points in *Fact Flash 5: Groundwater,* assigned for reading after the first class.

2. Explain that groundwater contamination is a major concern in the Superfund Program, and it is difficult to visualize how contaminants move underground. Therefore, the class is going to construct a small groundwater model to explore how groundwater and contaminants move in an aquifer.



3. Construct a miniature model of a groundwater environment. Choose 2 or 3 students to build the groundwater model at the front of the class. (If you have enough supplies, divide the class into 4 groups and have each group construct its own model.) Use the illustration shown on the next page as a guide.



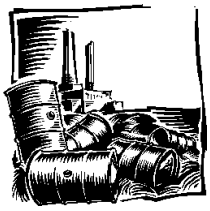
- Tape the pump mechanism, with the nylon fabric attached, to the inside of the container so that the nylon-covered end of the tube almost touches the bottom of the container.
- Fill the container about one-third full with the pebbles or gravel.
- Spread out the coffee filter and, if necessary, cut the paper to make a circle with a diameter larger than the diameter of the inside of the container. Place the filter paper on top of the pebbles and tape it to the sides of the container.
- Fill the rest of the container with sand. The filter paper will prevent the sand from falling down into the gravel and filling the spaces between gravel particles.

Your groundwater model is now ready for conducting experiments. Have students perform the following steps.

4. Spray water on the sand with the spray bottle, until the sand is saturated. The water will filter down through the sand and into the gravel. Keep spraying until the **water table** (the top of the portion of the ground that is completely saturated with water) is in the sand. Keep track of the amount of water that the container can hold at your selected water table level.

5. Push down on the pump mechanism and slowly draw a little water from the gravel through the tube and out of the pump. Make sure the pump empties into the measuring cup. Explain that the pump mechanism creates a vacuum to draw out the water. This is essentially the same method used to pump groundwater from **aquifers** (underground rock materials that are capable of storing and transmitting water in useful amounts).

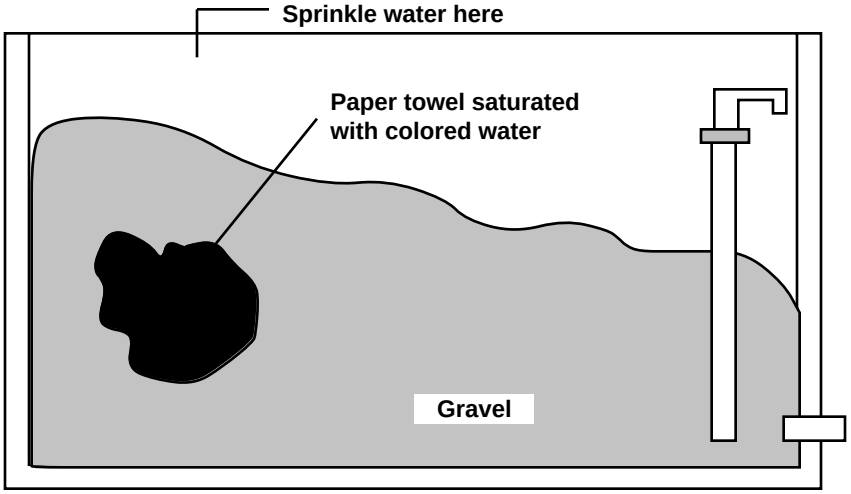
6. Spray more water on the sand until you reach your original water level. Then add a few drops of red food coloring on top of the sand. Place one of the drops near the edge of the sand, near the wall of the container. Explain to the students that the food coloring represents a hazardous waste, such as gasoline, that dissolves in water.



7. Make it rain on your aquifer model by pumping the spray bottle 5 times.

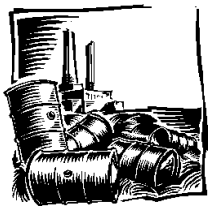
8. Continue pumping water from the container into the measuring cup. The water in the cup will eventually have a reddish hue. Keep track of how much water you have to pump from your groundwater model. Discuss with the students how the pollutant at the surface level has contaminated the groundwater. This is similar to rainwater carrying contaminants underground and into an aquifer. Can the students make any observations about how the pollutant moves downward through the sand from the drop placed by the wall of the container?

9. Ask students to guess how much clean water will have to be sprayed onto the sand to remove all of the food coloring. Continue adding water to the sand and removing water with the pump until the students believe your groundwater has been cleaned up. How much water did it take to clean the aquifer? Was this close to what the students guessed?



NOTE: Another way to illustrate this is to build your model using only gravel. Attach the pump mechanism the same way as for the other model. Roll a paper towel into a ball and saturate it with red food coloring. Bury it beneath the surface (in the gravel). The buried paper towel represents an abandoned waste site. Add water until 1/4 of the pump is submerged. Then spray more water on the surface until 1/2 the pump is under water. Press the pump 20 to 30 times, catching the water in another container. Have students discuss what they observe.

10. To simulate the addition and removal of other types of contaminants, you can put other additives into the water. For example, use molasses or maple syrup to represent a **dense non-aqueous phase liquid (DNAPL)**—a substance that is heavier than water and will not mix with water. Contaminants like TCE and PCB are DNAPLs. Use vegetable oil to represent a **light non-aqueous phase liquid**



(LNAPL)—a substance that is lighter than water and will not mix with water. Jet fuel is an LNAPL. The amount of water that will have to be flushed through the groundwater; model should be significantly greater to remove these contaminants than what was needed to remove the red food coloring.

11. Ask students how your small groundwater model represents contamination at a Superfund site. Answers could include:

    - Contaminants on the ground surface can be washed into groundwater by rainwater.
    - Contaminants in groundwater can be removed by pumping out contaminated groundwater; however, the amount of water needed to clean contaminants from groundwater is far greater than the amount of contamination added.

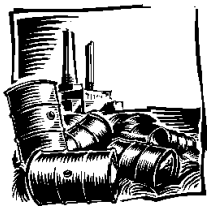
12. Ask students what is different between your experimental groundwater model and a real Superfund site. The following points could be made:

    - A Superfund site can have thousands of gallons of contaminants in the groundwater as opposed to a few ounces.
    - The subsurface at a Superfund site is far more complex than your groundwater model.
    - The water in your model is contained, but at a real Superfund site it almost always is flowing slowly in one direction. Flowing groundwater at a Superfund site can carry contaminants miles from where the contaminants were spilled on the surface. This can make it very difficult to locate a contaminant source once contaminated groundwater is detected.

13. Ask students to consider the situation at the fictional Flowing Railroad site. Would the residents of Utopia be in greater danger from contaminated groundwater if the groundwater beneath the Flowing Railroad site was flowing north toward Utopia or south away from Utopia? *(The answer is that residents would be in greater danger if the groundwater was flowing away from Utopia. This may sound surprising, but the reason is that, if the groundwater is flowing away from Utopia, it is flowing towards their drinking water wells located 3 miles south of the Flowing Railroad site.)*

Extensions (Optional)

- Separate the class into 3 groups. Have each group make a different model: (1) use red food coloring to simulate a water-soluble contaminant; (2) use the buried paper towel described in the note and illustration on previous page; and (3) use maple syrup to simulate a DNAPL and/or vegetable oil to simulate an LNAPL. Have students observe a demonstration of each model and discuss the differences.



- Consider inviting an EPA or state Superfund employee involved in overseeing hazardous waste cleanup projects to discuss a real Superfund site in your state and what made it a Superfund site.

- As an extra credit project, advanced students could use a computer model to predict the movement of contaminants in groundwater under various conditions. Check your local telephone directory for the nearest EPA or United States Geological Survey (USGS) office and contact them about obtaining a copy of the groundwater models they use on a personal computer disk.